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RHIC PROJECT

Brookhaven National Laboratory

Comments on the a_1, b_1 Correction System

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1. a_1 Correction System

ν–Shift Effect

Coupling introduces normal modes ν_1,ν_2.

Before Correction

$$|\nu_1 - \nu_2|_{max} = 228 \times 10^{-3} \quad \beta^* = 2$$

$$|\nu_1 - \nu_2|_{max} = 80 \times 10^{-3} \quad \beta^* = 6$$

(G. Parzen, AD/RHIC–AP–81, 1989.)

Global Correction System

a_1 correctors in insertions at Q2 and Q5. Two families for each β^*. Q2 and Q5 for $\beta^* = 6$. Q2 for $\beta^* = 2$.

After Correction (Residual $\Delta\nu$)

$\Delta\nu_{11}$ Stopband = 0 (Correct to make stopband = 0)

$$|\nu_1 - \nu_2|_{max} = 15 \times 10^{-3} \quad \beta^* = 6$$

$$|\nu_1 - \nu_2|_{max} = 20 \times 10^{-3} \quad \beta^* = 2$$

Empirical Correction (Correct to minimize $|\nu_1 - \nu_2|$)

$$|\nu_1 - \nu_2| = 7 \times 10^{-3} \quad \beta^* = 6$$

$$|\nu_1 - \nu_2| = 12 \times 10^{-3} \quad \beta^* = 2$$

Some additional a_1 correctors needed to reduce $|\nu_1 - \nu_2|$.

Note the advantage of setting correctors empirically, rather than setting them to cancel the $\nu_x = \nu_y$ stopband.

Betatron Distortion due to Random a_1

Indicated by large β_1,β_2 – $\Delta\beta/\beta \simeq 60\%$ found.

Betatron distortion measured by coupling distribution factor, CDF

$$CDF = \frac{X_{max}(s)}{X_{max}(s)_{a_1=0}} \text{ for given } x_o, x'_o, y_o, y'_o$$

Usual assumption, $CDF \simeq 1.4$ for $\epsilon_{x,o} = \epsilon_{y,o}$. Computer study gives

$$(CDF)_{max} \simeq 2$$

Consequences of Large CDF – Aperture Loss

a) Linear Aperture Loss

Calculations of aperture required, e.g. the extraction magnet, can be off by 40%.

b) Dynamic Aperture Loss (A_{SL} loss)

At some QF, A_{SL} can be reduced by 40%. Average loss A_{SL} about 15%. (G. Parzen, AD/RHIC–AP–80, 1989.)

Residual $|\nu_1 - \nu_2|$ and CDF Correction

Proposal: Separately excited a_1 near each high β quad in the insertions. Twelve separately excited a_1 near Q2.

This was also suggested by Correction System Review Committee.

This may correct both residual $|\nu_1 - \nu_2|$ and the CDF.

a_1 correctors near QD in arc may also be helpful but may not be necessary.

The above 3 effects, (1) the residual $|\nu_1 - \nu_2|$, (2) the high CDF and (3) the loss in A_{SL}, deserve careful consideration before giving up the a_1 correctors in the arcs.

The a_1 at Q2 are excited in two families to generate the cos and sin of the $\nu_x + \nu_y$ harmonic. This gives a total of 4 knobs in the a_1 correction system to control $|\nu_1 - \nu_2|$ and the CDF.

Note that again the Q2 correctors are set empirically to reduce the CDF and the residual $|\nu_1 - \nu_2|$. They are not set to cancel out a $|\nu_x + \nu_y|$ stopband.

Are two knobs sufficient to control the CDF and the residual $|\nu_1 - \nu_2|$? Some judgment is needed as to what level of correction is sufficient.

2. The b_1 Correction System

$\Delta\beta/\beta$ Effects of Random b_1

$$\beta^* = 6 \quad (\Delta\beta/\beta)_{max} = 0.36$$

$$\beta^* = 2 \quad (\Delta\beta/\beta)_{max} = 0.90$$

$(\Delta\beta/\beta)_{max} = 0.20$ comes from the arcs. Largest effect from Q1, Q2, Q3, $\beta^* = 2$. (G. Parzen, AD/RHIC–AP–71, 1988.)

Above is a large effect and needs correction. Most of this effect can be corrected using b_1 corrections in the insertion quads.

Proposal: Use the b_1 corrections in the insertion quads to also correct the 20% effect due the arc magnets, as well as the large effect due to Q1, Q2, Q3.

Note that the a_1 effects and b_1 effects are similar and of the same order. The b_1 effects only appear smaller because of the availability of correction coils that are already there for other reasons. Both a_1 and b_1 produce a ν–shift, a betatron distortion, and a loss in dynamic aperture.

Using the b_1 coils in the insertions makes the b_1 correction system and the a_1 correction look similar.

Proposal: Use 4 knobs in the Q2, Q3 magnets to control the effects of the $2\nu_x$ and $2\nu_y$ resonances on $\Delta\beta_x/\beta_x$ and $\Delta\beta_y/\beta_y$. This will produce a certain level of correction which may be sufficient. More knobs could be added, but would be difficult to use.

Why Correct b_1?

b_1 effects may be larger than expected because of

a) difficulty in correcting Q1, Q2, Q3
b) closed orbit errors in sextupoles
c) other various sources
d) operating near the integer ν–value.

3. Dispersion Correction

$$\frac{\Delta X_p}{X_p} = 0.25 \quad \text{at QF}$$

$$\frac{\Delta Y_{p,max}}{Y_p} = 0.31 \quad \text{at QD}$$

Mostly from arc magnets. (G. Parzen, AD/RHIC–AP–71, 1988.)

Reasons for Correcting X_p, Y_p

1) Effect on beam–beam interaction
2) To be able to operate near integer, $\nu \simeq 29$, where effect maybe about 3 times larger.

Proposal:

1) Use a_1 correctors at QD in arcs to correct Y_p. Possible a_1 corrector near Q9 as a back–up correction.

2) Use b_1 correctors at QF in arcs and b_1 in insertion quads to correct X_p.

The only new correctors required by the proposals in this note are the a_1 correctors at each Q2 in the insertions.